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REPORT NO. DPS TW-414/2

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AUTOMOTIVE DIVISION

REPORT ON

PERFORMANCE OF CONFINED-COLUMN TYPE APPLIQUE ARMOR UNDER COMBAT ATTACK (U)

Second Report on Ordnance Project No. TW-414

(D. A. Project No. 541-03-001)

(AD-1279)

FC

S. M. KEITHLEY

DECEMBER 1959

Aberdeen Proving Ground
Maryland

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DEVELOPMENT AND PROOF SERVICES
ABERDEEN PROVING GROUND
MARYLAND

AUTHORITY: OTAC Ltr 400.112   SMKeithley/mog/48264
Dated 16 Oct 1958
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PERFORMANCE OF CONFINED-COLUMN TYPE APPLIQUE ARMOR UNDER COMBAT ATTACK (U)

Second Report on Ordnance Project No. TW-414

Dates of Test: February to September 1959

ABSTRACT (C)

Two applique assemblies, each consisting of three sections (right, center and left), were designed by Ordnance Tank-Automotive Command for supplementing the armor of the front-hull area of current combat tanks. Both assemblies were of the same basic geometrical configuration and were constructed in a manner to take advantage of the effectiveness of a confined column for defeating shaped-charge ammunition. Each assembly was fabricated with a steel front and rear plate and a core of asphalt-filled tubing. The tubing of one assembly had a square cross section while the tubing of the second assembly had a hexagonal cross section. Three sections were fabricated using a full-penetration-weld joint and three sections were fabricated using a structural type weld joint. The 3.5-inch, M28A2, HEAT rocket head, statically detonated, the 106-mm, M344, HEAT projectile, dynamically fired, and the 105-mm, M1, HE projectile, dynamically fired with fuze on delay, were used to evaluate the applique assemblies. The applique assemblies were mounted for testing on an M48 tank hull after the mounting lugs furnished with the assembly were positioned and welded. Excessive weld cracking was observed for both type weld joints (full-penetration and structural) during testing. The applique offered considerable added protection against shaped-charge attack.

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CONTENTS (U)

1. (C) INTRODUCTION

With the development of new and improved weapons, greater emphasis is being placed on supplementary armor to provide the additional ballistic protection required by current armored vehicles. Applique armor is one means of supplementing the armor of current combat vehicles.

An applique assembly (Reference 1) consisting of three sections (right, center and left), each composed of an upper and lower panel, was tested at Aberdeen Proving Ground during the period December 1955 to February 1956. All panels were 6 inches thick, had a steel front and rear plate, and a core of glass and ensolite.

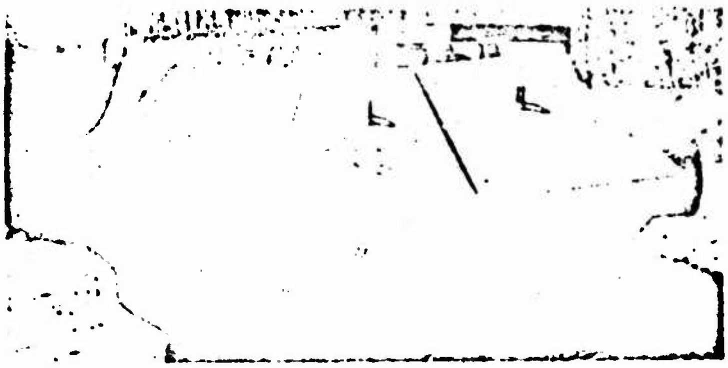

Figure 1 - 59T1231: Applique Assembly Installed on an M48A2 Tank Hull.

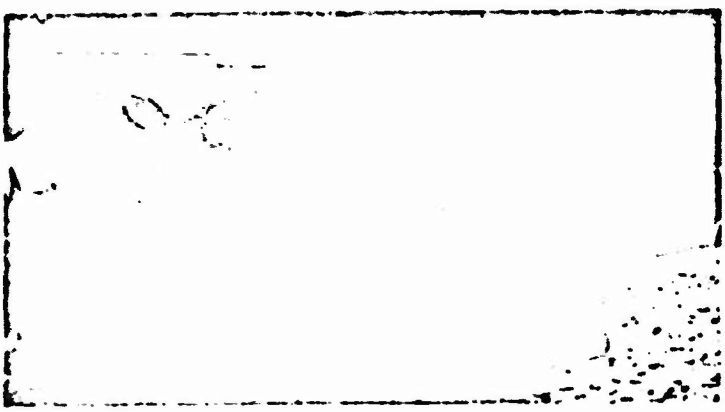

Figure 2 - 59T1230: M48A2 Tank Hull with Mounting Lugs Welded in Place.

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The applique assemblies covered by this report were of the same basic geometrical configurations as the applique previously tested, except that the over-all thickness of each panel is 4-3/8 inches. The core of the new applique kits was designed to take advantage of the effectiveness of a confined column for defeating shaped-charge ammunition.

Carnegie Institute of Technology conducted a great deal of research toward the design of a practical confined-column applique. Two cell geometries (square and hexagonal cross section) were chosen because, although not quite as effective as a circular cell of equivalent dimensions, they have the advantage of eliminating intracellular voids (Fig. 3). The geometrical features of an "oblique hexagonal prototype" tested by C. I. T. are shown in Figure 4.

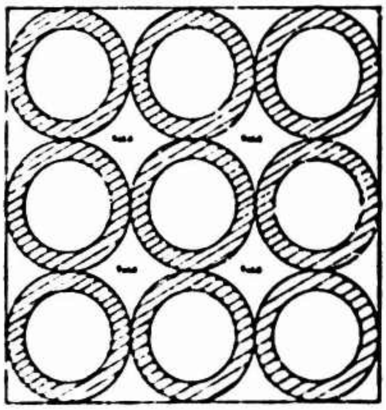

Figure 3: Circular Cell Arrangement Depicting Intracellular Voids. The Voids and Cells Would Be Filled with the Filler Material.

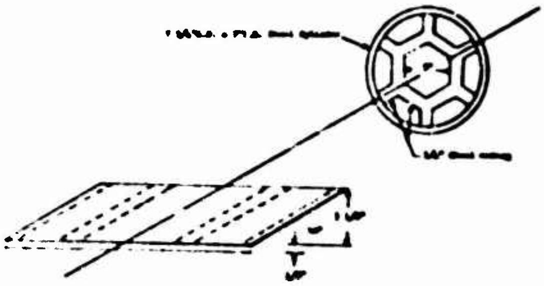

Figure 4: Geometrical Features of An "Oblique" Hexagonal Prototype Confined-Column Cell.

Asphalt was selected as the filler material because of its reasonably high effectiveness in reducing shaped-charge-jet penetration (Reference 2). It was also considered a suitable column material because of its low density (1.1 gm/cm³) and its semisolid character at ordinary temperatures.

2. (C) DESCRIPTION OF MATERIEL

The complete applique assembly (Figures 1 and 2) for the M48 tank hull consisted of three sections (right, center and left), 11 mounting lugs, 11 mounting-lug pins, and 22 mounting-pin-retaining snap rings. The complete assembly weighed approximately 3000 pounds.

The outside cover of the applique sections was fabricated from 1/2 inch rolled homogeneous steel armor. Two welding procedures, full-penetration and structural, were used to fabricate the applique sections (Figures 5 and 6).

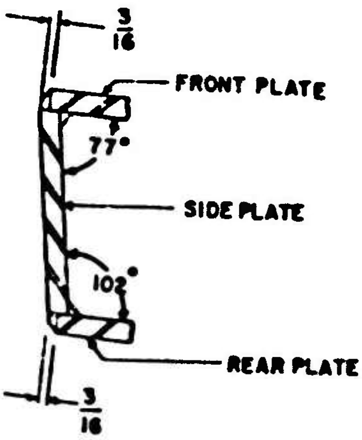

Figure 5: Cross Section of Applique Section Fabricated with Structural Type Weld Joint.

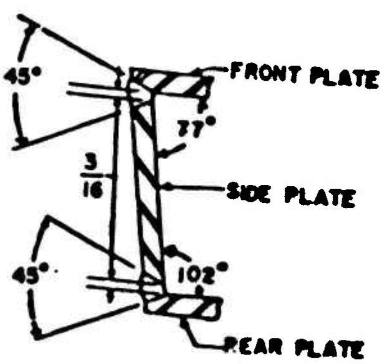

Figure 6: Cross Section of Applique Section Fabricated with a Full-Penetration Weld Joint.

The core of the applique kits under test was EAX steel tubing with an inside diameter of 3 inches, filled with asphalt (Figures 7 and 8). A cutaway view of the applique assemblies, prior to the addition of asphalt, is shown in Figures 9 and 10. Foundry sand was used to fill all voids between the outer plate and cells (Figures 7 and 8). Foundry sand was also sprinkled over the outside tubings prior to the attachment of the face plates. Three sections utilized square tubing (Fig. 9) and three utilized hexagonal tubing (Fig. 10).

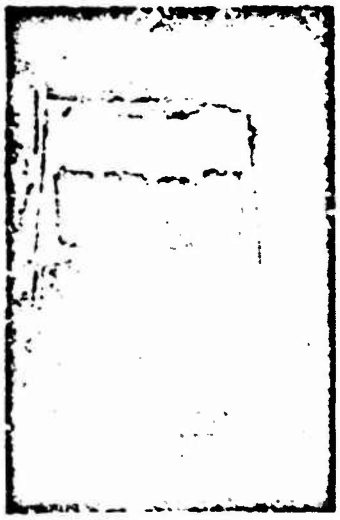

Figure 7: Cutaway of Upper Glacis of Center Applique with Square Tubing Filled with Asphalt.

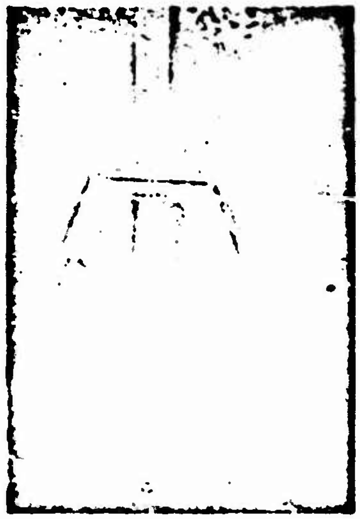

Figure 8: Cutaway of Lower Glacis of Center Applique with Hexagonal Tubing Filled with Asphalt.

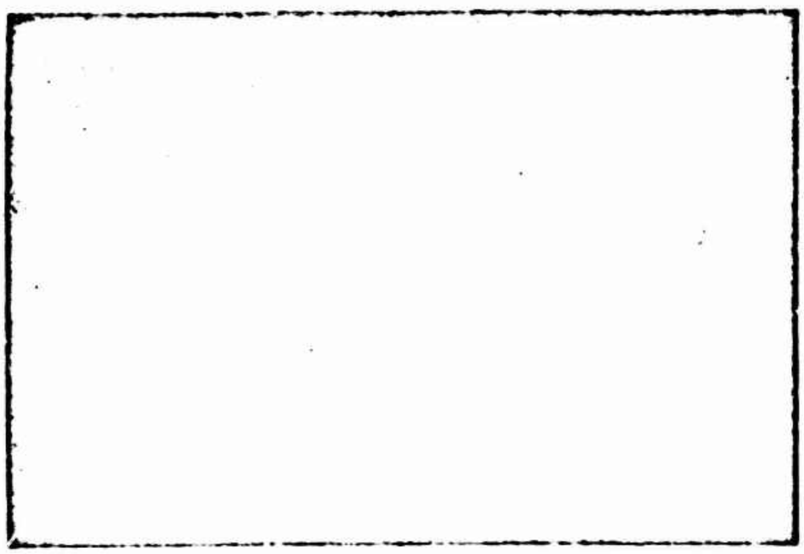

Figure 9: Cutaway View of Applique Assembly (Square Tubing) Prior to Addition of Asphalt.

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Figure 10: Cutaway View of Applique Assembly (Hexagonal Tubing) Prior to Addition of Asphalt.

3. (C) DETAILS OF TEST

3.1 Procedure and Results

3.1.1 Installation. A complete applique kit was installed on an M48A2 tank hull (Fig. 1) using the lugs and pins supplied. Mounting was accomplished by supporting the sections in position one at a time and tack-welding the lugs in place. After this the section was removed and the welding of the lugs completed. Considerable difficulty was encountered during the positioning and welding of the mounting lugs. Also it was difficult to locate the mounting lugs properly because of the irregular contour (Fig. 2) of the M48A2 tank hull.

The lifting eyes of the applique sections are located so that when the applique sections are lifted, the upper section is parallel to the upper glacis of the hull. This is satisfactory for the center section, but the outside sections should be tilted out slightly because of the curvature of the hull.

The second set of applique sections would not fit on the hull prepared for the first set. It was necessary to remove and reposition some of the lugs.

3.1.2 Ballistic Testing. The firing test was composed of three phases: 3.5-inch, M28A2, HEAT rocket head statically detonated; 106-mm, M344, HEAT projectile fired dynamically; and the 105-mm, M1, HE projectile fired dynamically with fuze set at delay. Each of the six applique sections was evaluated independently because there were no two alike. Full-penetration and structural-type joints are abbreviated FP and ST, respectively, in the text that follows. The applique sections with square tubing are designated by S and those with hexagonal tubing by an H.

The location of impacts for each applique section, by panel, may be found in Appendix B.

3.1.2.1 3.5-Inch, M28A2 Rocket Head, Statically Detonated. Twenty-four rounds of 3.5-inch, M28A2 HEAT rocket head, Lot MA-GK-9-57, were statically detonated against the applique sections. The nose of the rocket head was placed in contact with the front plate of the applique section, parallel to the longitudinal axis of the hull. Detailed data, including the number of rounds detonated, residual penetration, and applique weld cracking for each section, are found in Tables I through V.

3.1.2.2 106-mm, M344, HEAT Projectile, Fired Dynamically. Ten rounds of 106-mm, M344, HEAT projectiles, Lot MA-4-9, were fired dynamically in direct frontal attack. The recoilless rifle was 150 feet from the tank hull. Detailed data including the number of rounds fired, residual penetration, and applique weld cracking for each section are found in Tables I through V.

3.1.2.3 105-mm, M1, HE Projectile, Fired Dynamically. Two 105-mm, M1, HE projectiles, Lot RA-5CS-5, were fired dynamically, with the fuze set at delay, from a direct frontal attack. A Zone 7 charge was used with the 105-mm howitzer, M2A1, located 150 feet from the tank hull. Detailed data from each round are tabulated in Tables V and VI.

Table I. Firing Data for ST-H Center Section

Round Number	Type Round	Results to Applique	[b]Penetration of Hull	Total Residual Penetration in [a]Armor After Penetrating Applique (in Inches)
1	106-mm HEAT	Rubber shock pads fell off.	P	Slug prevents probe measurement.
2	Same	Lifting eye knocked off.	P	6.5
3	Same	No cracking.	C	10.8 (After penetrating the applique and 10.8-inch armor it made a 1/4-inch hole in rear of hull.)
4	Same	No cracking.	P	4.5
27	3.5-inch Rocket	No cracking.	P	2.5
32	Same	Caused 30.5 inches of weld cracking.	C	8.6
35	Same	Produced 40 inches of weld cracking.	P	5.0
38	106-mm HEAT	The upper face plate was knocked off and the hexagonal "cylinders" fell out.	C	7.6

[a]The portion of penetration in the mild steel backup plate was converted to equivalent penetration in armor.
[b]Complete penetration of hull indicated by C, partial penetration by P.

Table II. Firing Data for FP-8 Center Section

Round Number	Type Round	Results to Applique	[a]Penetration of Hull	Total Residual Penetration in Armor After Penetrating Applique (in Inches)
6	106-mm HEAT	14-inch weld cracking. 4-inch plate cracking.	C	8.9
17	3.5-inch Rocket	20-inch weld cracking.	P	Slug prevented probe measurement.
18	Same	No cracking.	C	7.6
19	Same	20-inch weld cracking.	C	5.5
20	Same	26-inch weld cracking.	P	3.5
24	106-mm HEAT	8-inch weld cracking.	C	6.9

[a]C = Complete penetration - P = Partial

Table III. Firing Data for ST-H Left Section

Round Number	Type Round	Results to Applique	Penetration of Hull	Total Residual Penetration in Armor After Penetrating Applique (in Inches)
8	3.5-inch Rocket	No cracking.	C	4.75 [a]Plus
12	Same	No cracking.	P	5.5
13	Same	No cracking.	P	5.0
14	Same	No cracking.	C	6.2 [a]Plus
15	3.5-inch Rocket	28-inch weld cracking.	P	4.0
16	Same	No cracking.	C	4.75 [a]Plus
5	106-mm HEAT	34-inch weld cracking.	P	5.5
7	Same	20½-inch weld cracking.	P	6.0
23	Same	Lower panel face plate fell off, hexagonal tubing fell out on ground.	P	5.0

[a]Residual penetration after hull was not measured.

C = Complete penetration - P = Partial

Table IV. Firing Data for FP-S Left Section

Round Number	Type Round	Results to Applique	[b]Penetration of Hull	Total Residual Penetration in Armor After Penetrating Applique (in Inches)
28	3.5-inch Rocket	No cracking.	P	2
29	Same	No cracking.	P	4.5
30	Same	No cracking.	C	4.2 [a]Plus
31	Same	13-inch weld cracking.	C	4.5 Plus
34	Same	48-inch weld cracking.	P	4.5
36	Same	No cracking.	P	Slug prevents probe measurement.
37	Same	No cracking.	P	3
39	106-mm HEAT	No cracking.	P	7.5

[a]There was no backup armor behind this section.

[b]P = Partial penetration - C = Complete.

Table V. Firing Data for ST-8 Right Section

Round Number	Type Round	Results to Applique	Penetration to Hull	Total Residual Penetration in Armor After Penetrating Applique (in Inches)
9	3.5-inch Rocket	No visible cracking.	C	4.3
10	Same	No visible cracking.	P	5.5
11	Same	No visible cracking.	P	3.5
21	Same	No visible cracking.	P	4.5
22	105-mm HE	Welds on the mounting lugs, braces, face plate and rear plate failed, which caused the applique to break in half and fall off the hull. Some of the square cells fell out.		

15-1/2 inches of cracking were produced on this section from Round 6, which was fired on the right edge of center section FP-8.

C = Complete penetration - P = Partial.

Table VI. Firing Data for FP-H Right Section

Rd No.	Type Round	Results to Applique	Results to Hull
26	105-mm HE	Welds on mounting lugs failed and applique fell off hull. There was also a small amount of weld and plate cracking in impact area.	None

Table VII. Summary of Firing Data

Section and Panel	No. and Type Round That Did Not Penetrate Hull After Passing Through Applique	Avg Penetration in Hull after Jet Penetrated Applique, inches	No. and Type Round that Penetrated Applique and Hull	Total Armor Penetration after Jet Passed Through Applique for Rounds which had Backup Material Inside the Hull, inches
FP-S Left Upper	2 3.5-inch Rocket 1 106-mm HEAT	3.25 7.5		
FP-S Left Lower	3 3.5-inch Rocket	3.75	2 3.5-inch Rocket	
ST-H Left Upper	3 106-mm HEAT	5.5		
ST-H Left Lower	3 3.5-inch Rocket	4.83	3 3.5-inch Rocket	
FP-H Right Upper	1 105-mm HE	——	—	
ST-S Right Upper	1 105-mm HE	——	—	
ST-S Right Lower	3 3.5-inch Rocket	4.5	1 3.5	
FP-S Center Upper			2 106-mm HEAT	7.9
FP-S Center Lower	2 3.5-inch Rocket	3.5	2 3.5-inch Rocket	5.55
ST-H Center Upper	1 3.5-inch Rocket 3 106-mm HEAT	2.5 5.5	1 106-mm HEAT	7.6
ST-H Lower	1 3.5-inch Rocket	5.0	1 3.5-inch Rocket 1 106-mm HEAT	8.6 10.8 plus

3.1.3 Summary of Results. A tabulated summary of the firing data is presented in Table VII. A tabulated summary of the results for the previous composite applique assembly tested (Reference 1) is presented in Table VIII. A comparison of the penetration data for the three type applique assemblies is presented in Table IX. It should be noted that a limited number of rounds were fired under any one condition during this and the previous (Reference 1) test; therefore, the above comparison (Table IX) should be used with caution.

Table VIII. Summary of Penetration Data of Composite (Glass-Ensolite) Applique Assembly[a]

		Average Depth of Hull Penetration, inches		
Panel	No. of Rounds Averaged	3.5" Rocket, Dynamic	106-mm, Dynamic	3.5" Rocket, Static
Upper Left	2	2-1/4	—	—
	1	—	—	4-5/8
Lower Left	4	1/8	—	—
	1	—	—	3
Upper Center	1	—	5	—
	2	—	—	4-3/16
Lower Center	1	—	Complete	—
	2	—	—	3-7/8
Upper Right	3	—	4-5/12	—
	1	—	—	5-1/8
Lower Right	4	—	[b]5	—
	1	—	—	3-1/2

[a]Data extracted from Reference 1.
[b]Complete penetration taken as 6 inches for use in calculating average.

Table. IX. Comparison of Penetration Data for the Hexagonal Tubing, Square Tubing, and Composite (Glass-Ensolite) Type Applique Assemblies

Type of Applique	Average Residual Penetration in Armor After Penetrating Applique, in inches			
	106-mm, M344 HEAT Projectile Dynamically Fired		3.5" M28A2 Rocket Head Statically Detonated	
	No. Rds	Penetration	No. Rds	Penetration
Composite, lower panels	5	5.0	4	3.75
Hexagonal, lower panels	—	—	8	5.4
Square, lower panels	1	10.8	13	4.4
Composite, upper panels	4	4.5	4	4.8
Hexagonal, upper panels	7	5.8	—	—
Square, upper panels	3	7.8	2	3.25

Note: The penetration data for the lower panels of the right, left, and center sections were averaged for this table since the lower panels are uniform in thickness and are positioned at approximately the same angle of obliquity (45°). The penetration data for the upper panels was averaged for the same reason.

A 105-mm HE projectile (Round 22), when fired into the upper panel of the right ST-6 section (Fig. 11), fractured the welds on the hull mounting lugs. The structural braces in the rear of the section also fractured and the section broke in half as it fell to the ground. The severe failure of the section as a result of the 105-mm, HE projectile impact is partially due to an accumulation of damage effect from the four previous 3.5-inch rocket heads statically detonated on the lower panel. The second 105-mm, HE projectile (Round 26), when fired against the upper panel of the right applique section FP-H (Fig. 12), which had received no previous impacts, broke the upper two mounting lugs off of the applique section and the lower two from the hull. There was some plate cracking at the point of impact and a small amount of weld cracking on the top edge of the section.

Excessive weld cracking was observed on the applique sections fabricated with both the structural and full-penetration type weld joints. After a number of rounds had been fired into a section or an adjacent section, the front plate opened enough for the asphalt-filled cells to fall out (Figures 13 and 14).

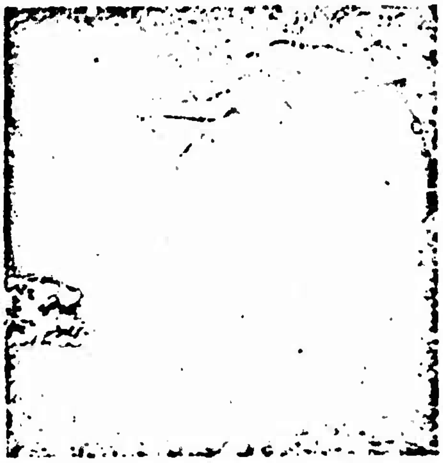

Figure 11 - 59T1406: Right ST-S Applique Section After Impact by One 105-mm, HE Shell on the Upper Panel and Four 3.5-Inch Rocket Heads Statically Detonated on the Lower Panel.

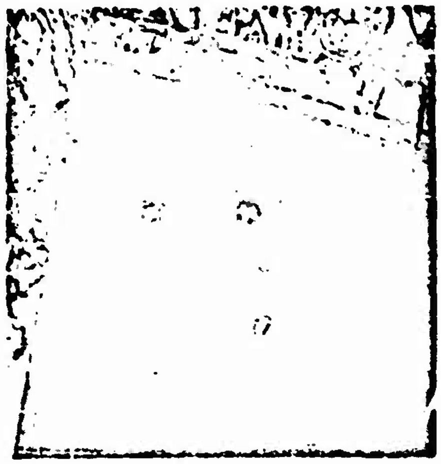

Figure 12 - 59T1405: Right FP-H Applique Section After Impact by One 105-mm, HE Projectile on the Upper Panel.

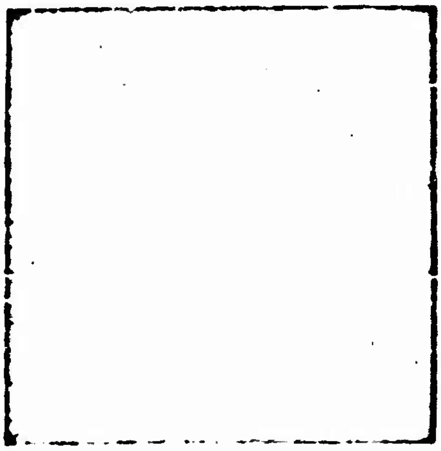

Figure 13 - 59T1404: Center FP-S Applique Section Depicting Severe Weldment Failure Caused From Successive Impacts.

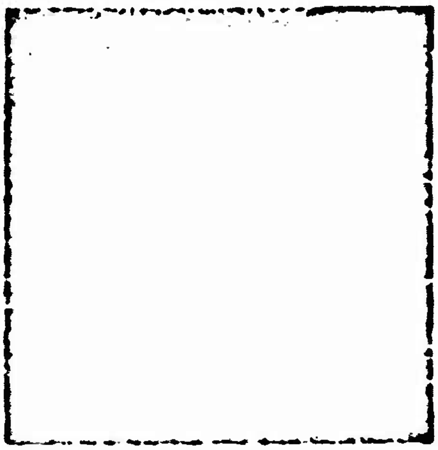

Figure 14 - 59T1402: Left ST-H Applique Section Depicting the Void Left by the Cells Which Fell Out After the Face Plate was Blown Off.

3.1.4 Observations. The asphalt filler did not catch on fire when the applique was impacted by the various types of ammunition used during the test. The heat produced by some impacts, however, melted the asphalt in the immediate area.

The rubber shock pads (Figures 15 and 16) which were designed principally to reduce the shock loads on the mounting lugs during cross-country operation, fell off the section when the first round on each section was fired.

The applique assembly was not designed to fit the M48 tank hull properly. When the rubber shock pads were in contact with the upper glacis (Fig. 16), the adjustment bolt contacted the lower glacis and could not be tightened properly. Also, the lower mounting lug could not be attached when the shock pads both were in contact with the upper glacis. Conversely, when the mounting lugs were in position and the adjustment bolt centered, both shock pads were not in contact with the upper glacis (Fig.16).

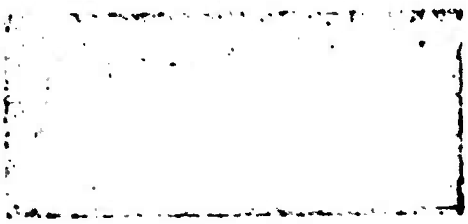

Figure 15 - 59T1407: Rubber Shock Pad Which was Knocked Off of the Rear of An Applique Section When Impacted by An 106-mm, M344 HEAT Projectile.

Figure 16 - 59T1233: Center Applique Section Mounted On An M48 Tank Hull, Depicting the Relative Positions of the Rubber Shock Pads and Adjustment Bolt in Relation to the Curvature of the M48 Tank Hull.

The applique section H-FP mounting lug weldments (Fig. 12), which fractured when impacted by an 105-mm, HE projectile, revealed there was little penetration of weld metal into the mounting lug metal.

4. (C) CONCLUSIONS

Based on the results of this test, it is concluded that:

a. The confined-column applique armor when mounted on an M48 tank hull affords considerable added protection against shaped-charge attack.

b. The welded construction of the confined-column applique panels tested was not effective in withstanding high-explosive-projectile impacts without extreme damage occurring.

c. The mounting lugs as presently attached to the applique are subject to possible displacement by shock and blast from projectile impacts.

d. No definite difference in the performance of the two shapes of tubing used in the applique could be noted.

e. Applique armor offers great promise for greatly increased protection against shaped-charge attack on the frontal area of tank hulls.

5. (C) RECOMMENDATIONS

It is recommended that:

a. Future tests of applique assemblies be conducted with the test material mounted on a flat cast or rolled armor plate rather than a tank hull, which has curvature and variable thickness and therefore does not give good data for comparative evaluation.

b. An interlock type of weld joint be used to attach the front and rear plates on the applique sections, since this type of welded construction provides an irregular path for weld fracture and should help to limit joint failure.

c. The mounting lugs be inset in the applique section and welded on the inside and outside to prevent displacement.

d. Adoption of the confined-column applique of the type tested for field use be withheld until definite improvements have been made in construction, and performance proved by additional tests.

e. Development of applique armor for the frontal area of tank hulls be continued to develop an effective and practical arrangement.

SUBMITTED:

S. M. Keithley

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Project Engineer

REVIEWED:

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Chief
Automotive Division

APPROVED:

H. A. Noble

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Assistant Deputy Director
for Engineering Testing
Development and Proof Services

REFERENCES (U)

1. Cawirey, P. M. Investigation of the Effectiveness of a Composite Armor Assembly in Defeating Shaped-Charge Attack. Forty-Second Report on OCO Project No. TT1-5. Aberdeen Proving Ground, Maryland, 12 June 1956. AD-307 752

2. Pugh, E. M. Defeat of Shaped-Charge Weapons. CAR IT SR-2, Carnegie Institute of Technology, 22 February 1958. AD-73 [illegible]

AD-103 526

APPENDICES (U)

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APPENDIX A
Correspondence

HEADQUARTERS
ORDNANCE TANK-AUTOMOTIVE COMMAND
DETROIT ARSENAL
28251 VAN DYKE AVENUE
CENTER LINE, MICHIGAN

DPSaxon/HSpiro/pm/24-106

IN REPLY
REFER TO OTAC/400.112(16 Oct 58)
ORDMC-RM.1

16 Oct 1958

SUBJECT: Ballistic Testing of Six (6) Proposed Armor Developmental Projects (U)

TO: Commanding General
Aberdeen Proving Ground, Maryland
ATTENTION: ORDBG-DP-TE
Mr. W. C. Pless

MAR CI-58-3360

REFERENCE: AOS-5350.60.268.0-213

1. Six (6) proposed armor projects, as noted below, are to be ballistically evaluated at Aberdeen Proving Ground (reference AOS).

a. Project I - Confined Column Applique.

b. Project II - Ambulance Body and Cupola.

c. Project III - Cast Armor of Varying Toughness.

d. Project IV - Low Carbon Cast Armor Plates.

e. Project V - Low Carbon Turret and Hull Castings.

f. Project VI - IR Grilles.

2. A Test Directive covering the above projects is inclosed for your information.

3. A cost estimate, as per Mr. I. Teichman on 25 February 1958, was for $54,000.00.

FOR THE COMMANDER:

5 Incl
1. Test Dir (C)
2-5. Photos (C)

/s/ C. S. Rasmussen
/t/ C. S. RASMUSSEN
Executive Assistant
Research & Development Division

Copy furnished:
OCO, Attn: ORDTW
w/incl Test Dir w/o photos

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SUBJECT: To Ballistically Test and Evaluate Six (6) Proposed Armor Development Projects

PROJECT I: Confined Column Applique Armor
Reference: APG Report, Final AD 1231

Description: This arsenal is sending to Aberdeen Proving Ground two front hull applique assemblies, each composed of 3 sections and attachments for ballistic evaluation (reference report). The new applique kits utilize the confined column principle. The materiel is NAX steel tubing (hexagonal or square) with inside diameter of three inches, filled with asphalt and covered with rolled homogeneous armor. The armor thickness is 3/8" except for the cover which is 1/2". The overall thickness is only 4-3/8" whereas the previous one (armor, ensolite and glass) was 6-1/8" (reference report). The applique kits are identified with welded lettering on the top edge of center assembly. The "H-FP" marking indicates that tubing is hexagonal and full penetration welding was used for attaching cover. The "S-S" marking infers that the tubing is square and structural welding was used for attaching cover.

Procedure: The first and then the second applique assembly respectively, is to be mounted on the hull of an M48 tank, using the lugs and pins supplied for ballistic testing. It is recommended that APG statically test the assembly with 3.5" HEAT and dynamically with the 106mm HEAT rounds, and then measure residual penetrations and other associated damage. Upon completion of HEAT testing, a 76mm and/or 90mm HE round, with delay fuze settings shall be impacted on the applique armor assembly at 60° obliquity for ... ge evaluation.

...JECT II: Ambulance Body and Cupola

Description: One (1) ambulance body utilizing 1/2" doron will be shipped to APG from the Detroit Arsenal and two (2) cupolas, one of which is fabricated with 1/2" and one (1) inch doron will be forwarded to APG from Aircraft Armaments.

Procedure:

a. Five (5) 105mm HE shells shall be detonated at 90 feet from the above vehicle and cupolas to determine their vulnerability to fragments.

b. Ten (10) fragmentation hand grenades shall be detonated on and adjacent to the above materials. The exact locations to be selected at a later date.

PROJECT III: Cast Armor of Varying Toughness

Description: Ten (10) cast homogeneous armor test plates (4" x 36" x 48") in accordance with Specification MIL-A-11356B except for variance in Charpy Levels, are to be shipped from Pacific Car and Foundry to APG to determine relationship between charpy and ballistics.

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The plates in groups of two, shall have the charpy values of 5 to 12, 10 to 18, 15 to 23, 22 to 30, and minimum of 38 ft/lb.

Procedure:

a. Ambient temperature. These plates shall be tested at -40°F with 90mm AP projectiles at 55° obliquity to determine its resistance to shock. Approximate Bl 2700 fps.

PROJECT 17: Low Carbon Cast Armor Plates

Description: Eighteen low carbon (.20 max) armor cast plates (6 pieces - 36" x 48" x 2"; 6 pieces - 36" x 48" x 3"; and 6 pieces - 36" x 48" x 4") are to be shipped to APG. Half of the plates to be from Pacific Car and Foundry and half from Pittsburgh Steel Foundry.

Procedure: The ballistic limit shall be determined for each plate thickness with AP projectiles as noted:

Thickness	Projectile	Obliquity	Temperature	Approx Bl
2	76mm AP T126E6	55	Ambient	2175
3	90mm	55	"	2400
4	90mm	55	"	2800
2	76mm	55	-40°F	2175
3	90mm	55	"	2400
4	90mm	55	"	2800

PROJECT 7: Low Carbon Turret and Hull Casting
Reference: a. Ltr, File #OTAC 470.5/APG, dtd 28 Mar 57
b. APG Final Report AD 1217
c. APG Final Report AD 1174
d. APG Final Report 1209

Description: Two (2) M48 low carbon hull castings and two (2) M48 low carbon turret castings to be sent to APG for ballistic evaluation. One set employing basic melting practice will be cast by General Steel Casting and one set acid melting practice by Blaw Knox Company. Blaw Knox's hull casting will be part of a hull assembly, complete with floor plate in accordance with Drawing No. 8734088. The fabrication will be accomplished with the use of ferritic electrodes and in accordance with Specification MIL-W-12518.

Two (2) ballistic test plates (36" x 36" x 2") from Blaw Knox will be forwarded to APG for testing.

Eleven (11) "H" test plates (36" x 36" x 1½"), 3 from Blaw Knox, and 8 from Detroit Arsenal, will be forwarded to APG. The welded armor data vellums will be forwarded to your office under separate cover.

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Procedure:

a. The ballistic test plates shall be tested in accordance with Specification MIL-A-11356S.

b. The hull and turret castings shall be tested with various projectiles to ascertain the level of protection afforded the lower carbon alloy (reference reports). The same test procedure should be used for the hull and turret as noted in reference APG reports A[illegible] and AD1217 respectively.

c. Blast Evaluation

(1) Ballistic shock tests of welded joints of Blaw Knox hull using same projectiles as utilized in reference report (AD-1209). The exact areas and type of projectile to be selected at a later date.

(2) The $1\frac{1}{2}$ inch cast armor "H" plates will be X-rayed and then ballistically shock tested utilizing a [illegible] projectile with a striking velocity of 1050 f/s plus or minus 25 f/s.

(3) The number of impacts to be placed on each "H" plate at ambient or -40°F will be determined at a later date by the project engineer.

d. Mine test procedure same as reported in reference report AD 1209.

PROJECT VI: JR Grilles

Reference: a. Ltr, File [illegible], dtd 7 Jul 55
b. Ltr, File [illegible] APG, dtd 8 Nov 57

Description: Sixteen (16) grilles - 4 lightweight intake grilles, 4 heavyweight intake grilles, 4 lightweight exhaust grilles and 4 heavyweight exhaust grilles, to be shipped to APG from Denver Research.

Procedure: The test procedure for the heavyweight grille and lightweight grille to be similar to that used for armored air grilles (reference a.) and T92 tank program (reference b.) respectively.

Remarks: The order and method of testing each of the above projects is left to discretion of APG. In addition, authorization is granted to conduct other tests which APG may deem necessary.

Attendance: This office desires to be notified in advance of the schedules for firing for each project to permit attendance by interested personnel.

Reports: Informal reports will be required for each project.

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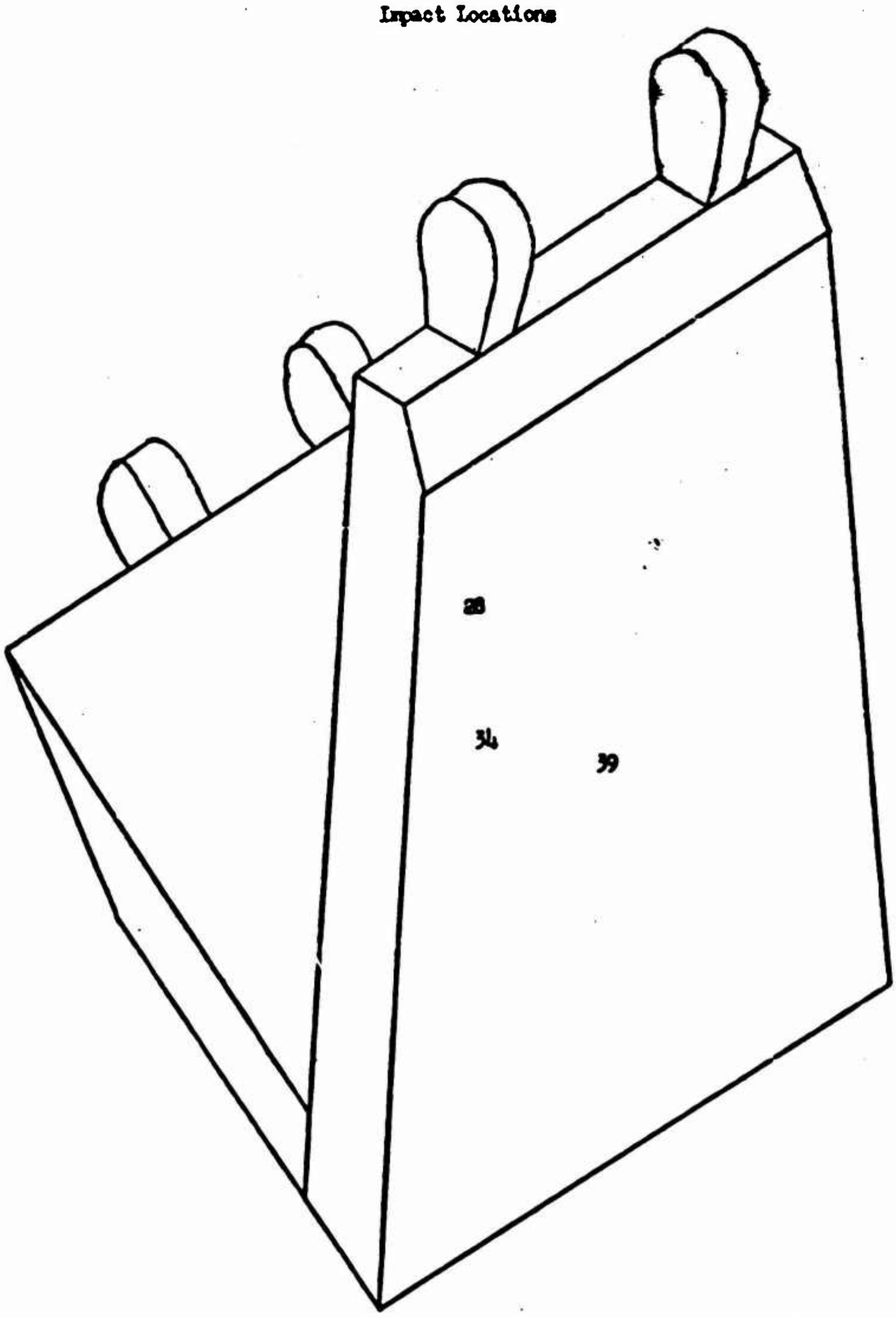
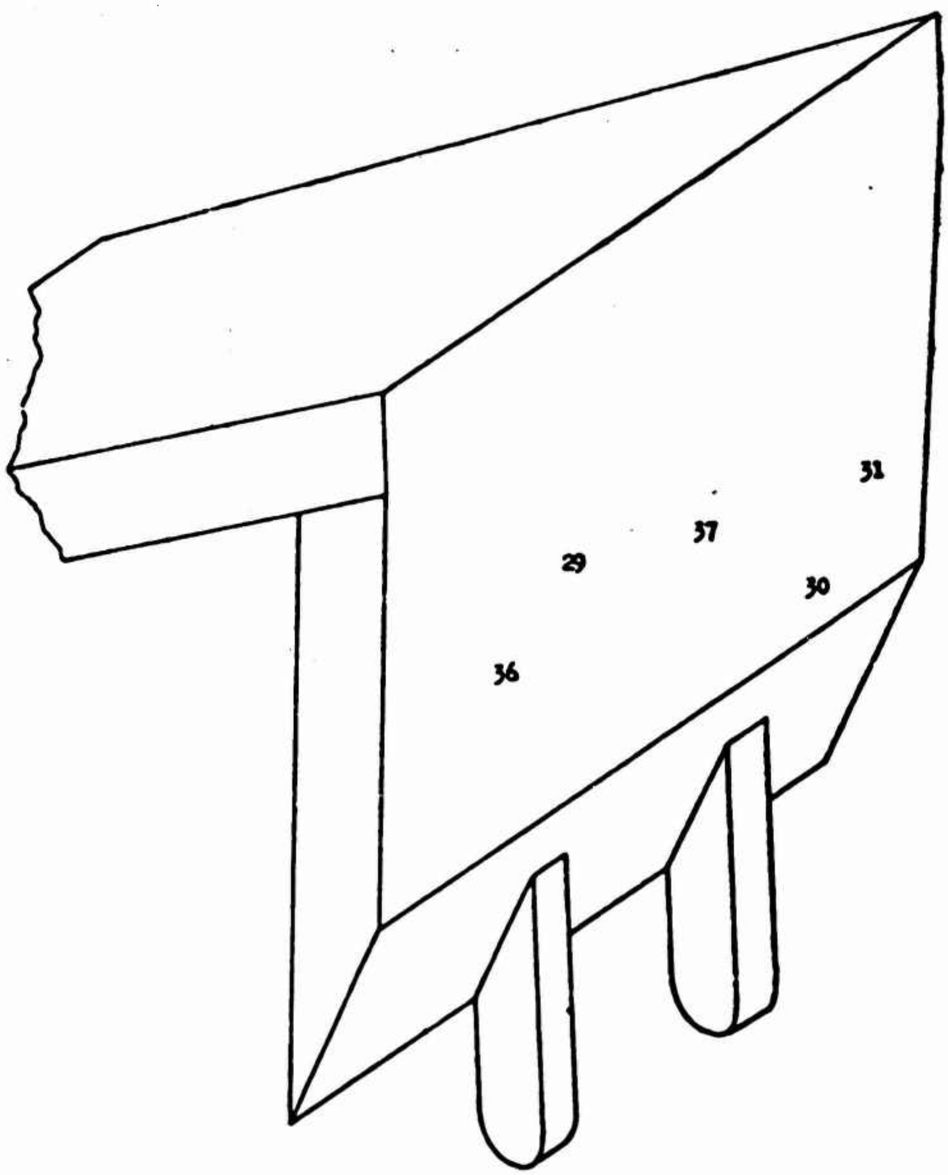
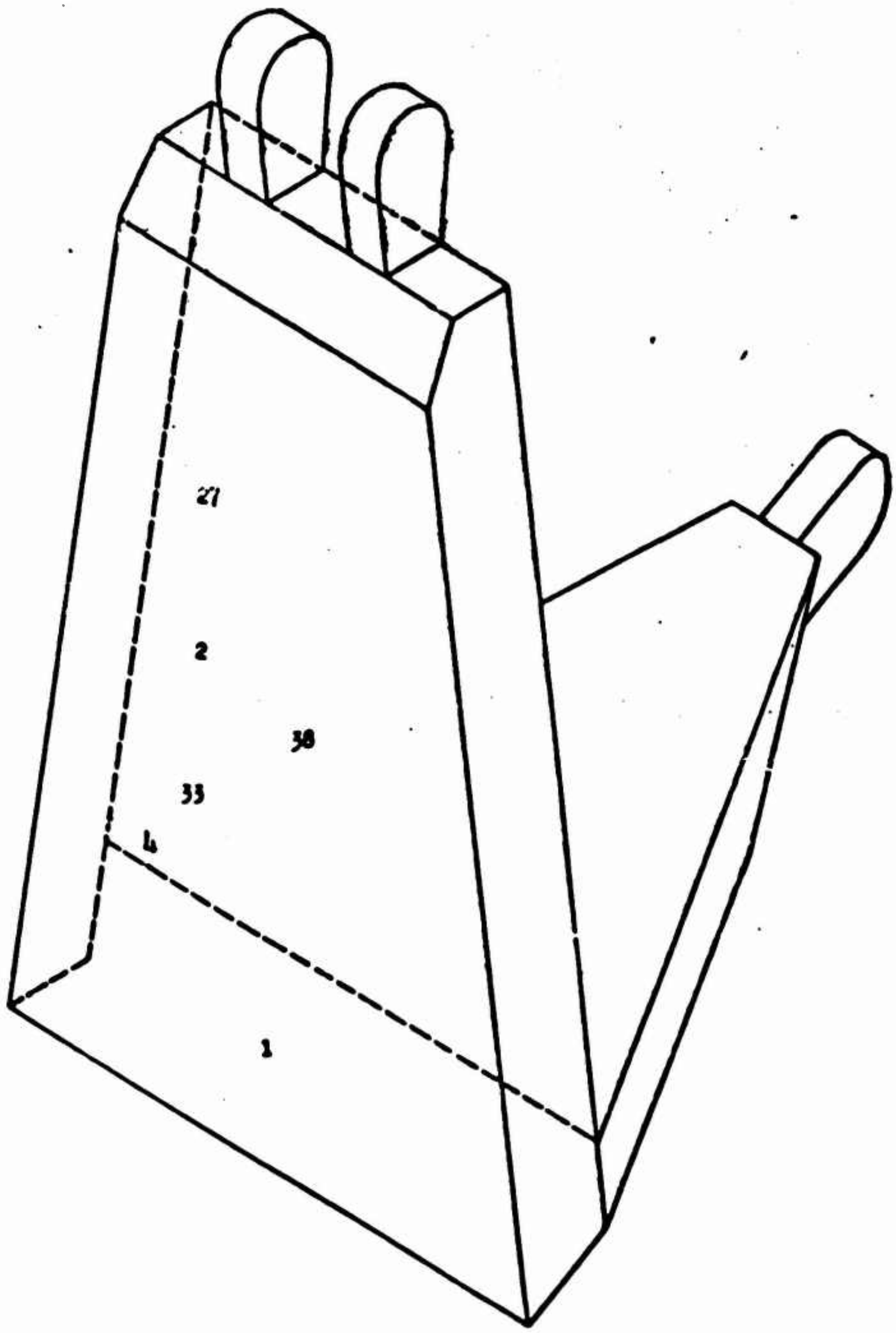
APPENDIX B
Impact Locations



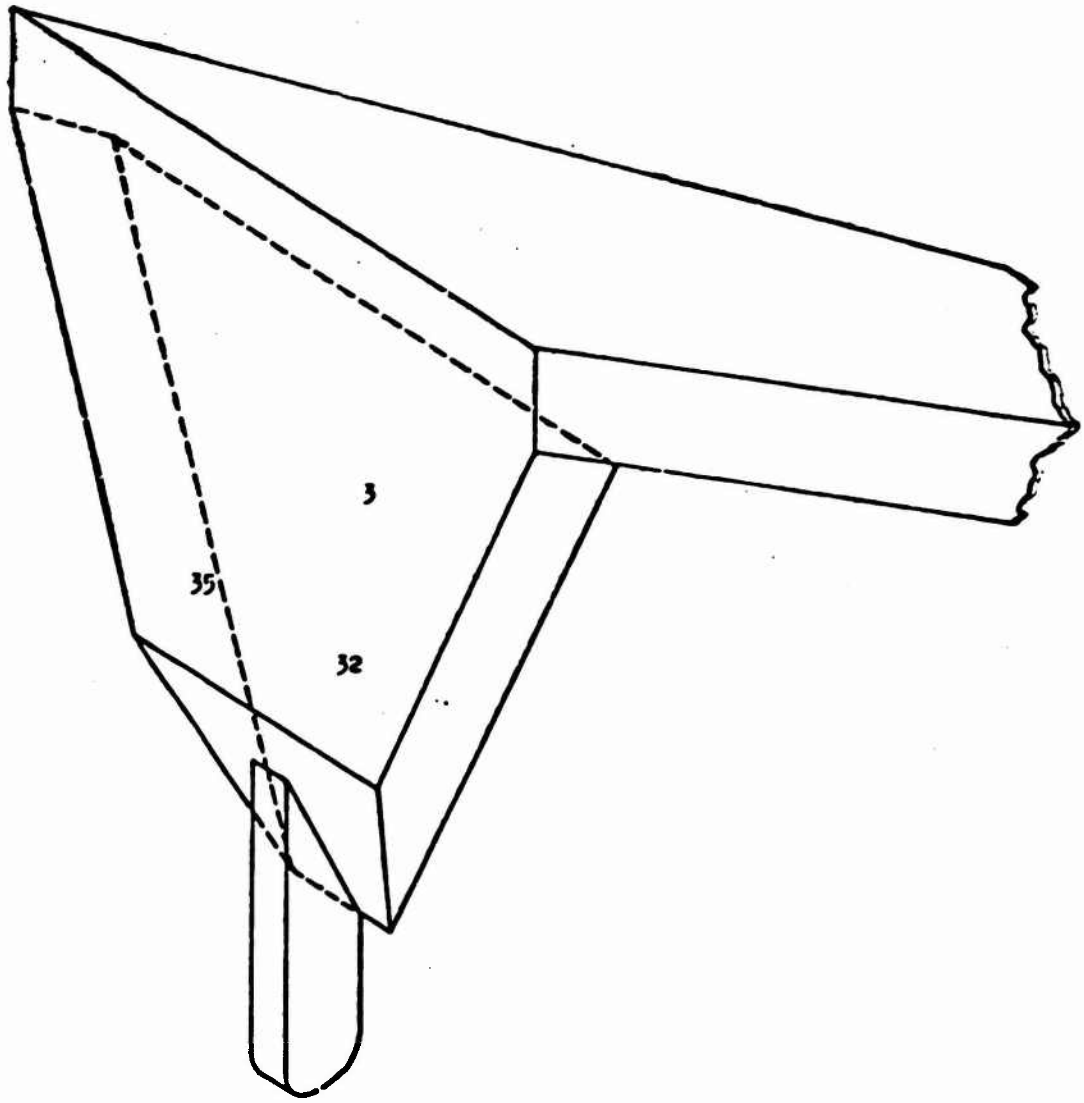
Upper panel, left section, full penetration type weld joint, square tubing showing location of hits by round number



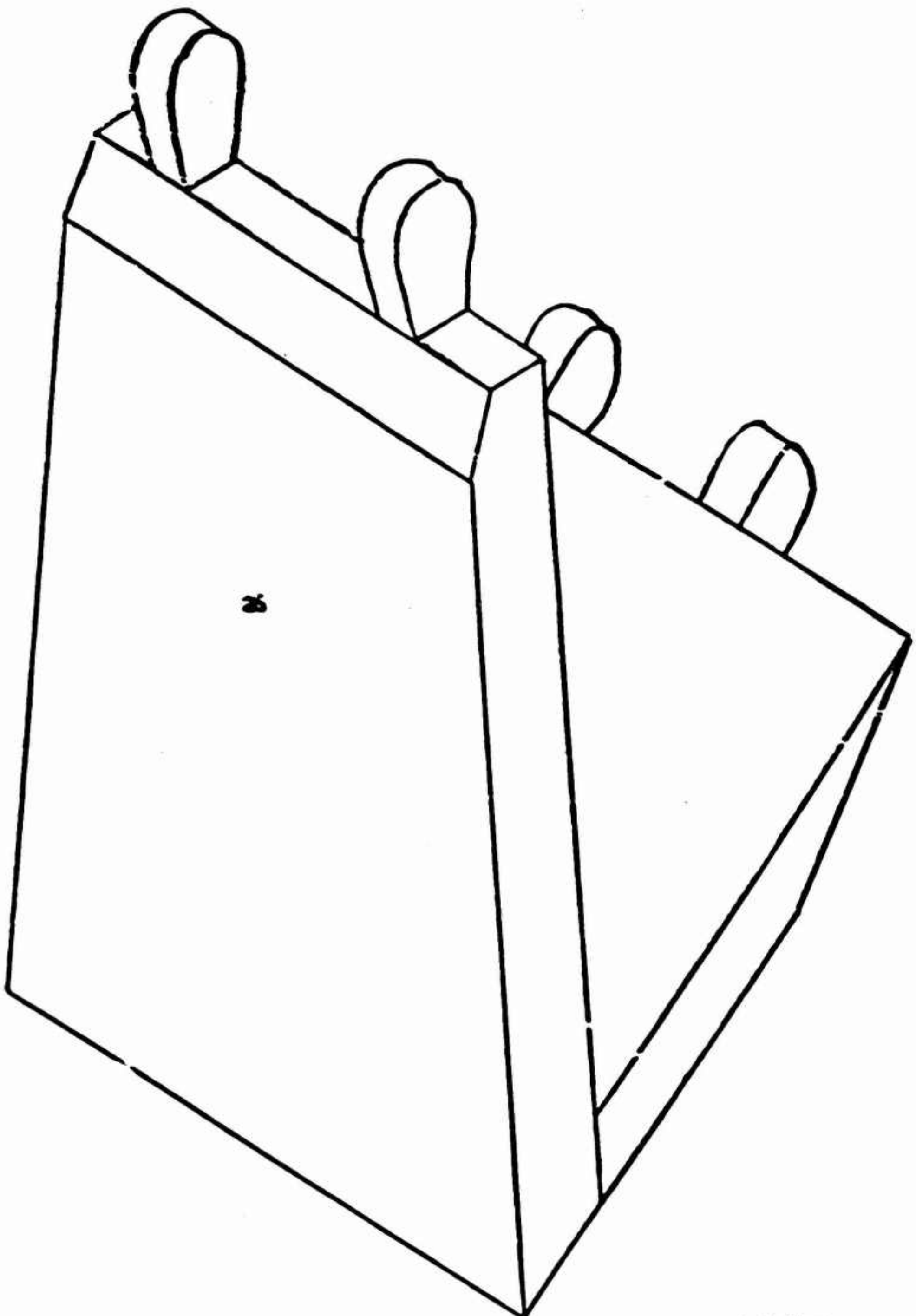
Lower panel, left section, full penetration type weld joint, square tubing showing location of hits by round number



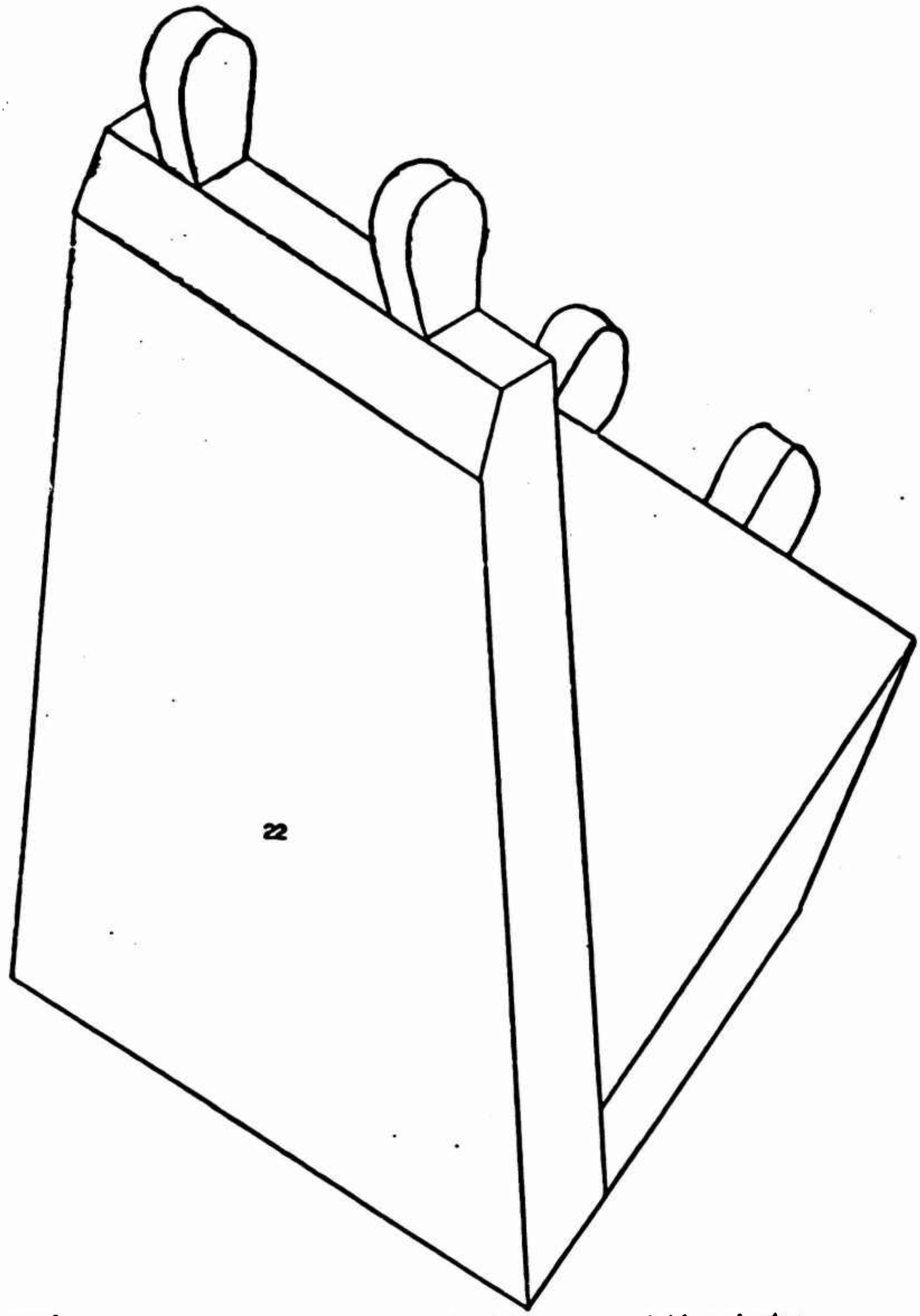
Upper panel, center section, structural type weld joint, hexagonal tubing showing location of hits by round number



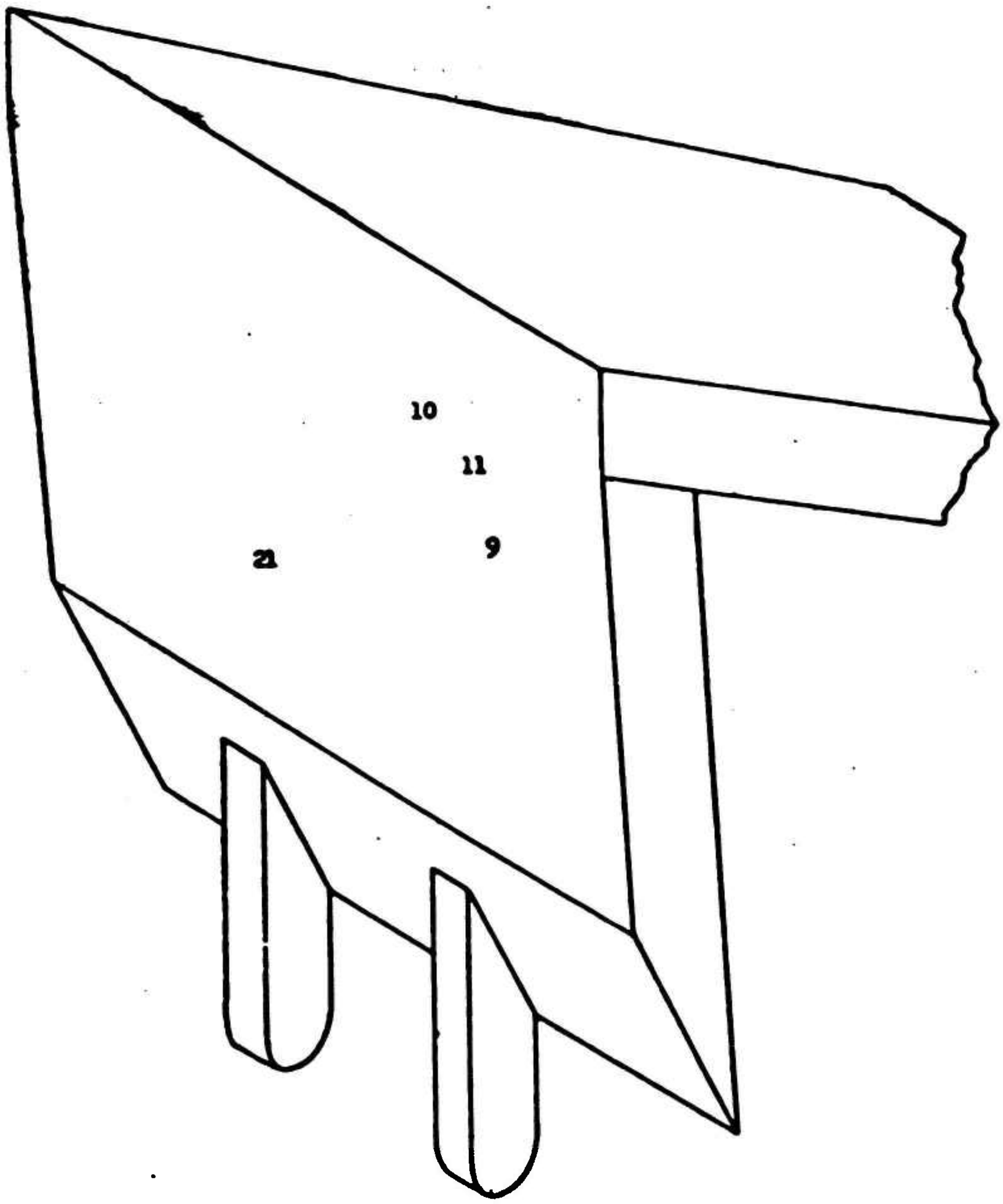
Lower panel, center section, structural type weld joint, hexagonal tubing showing location of hits by round number



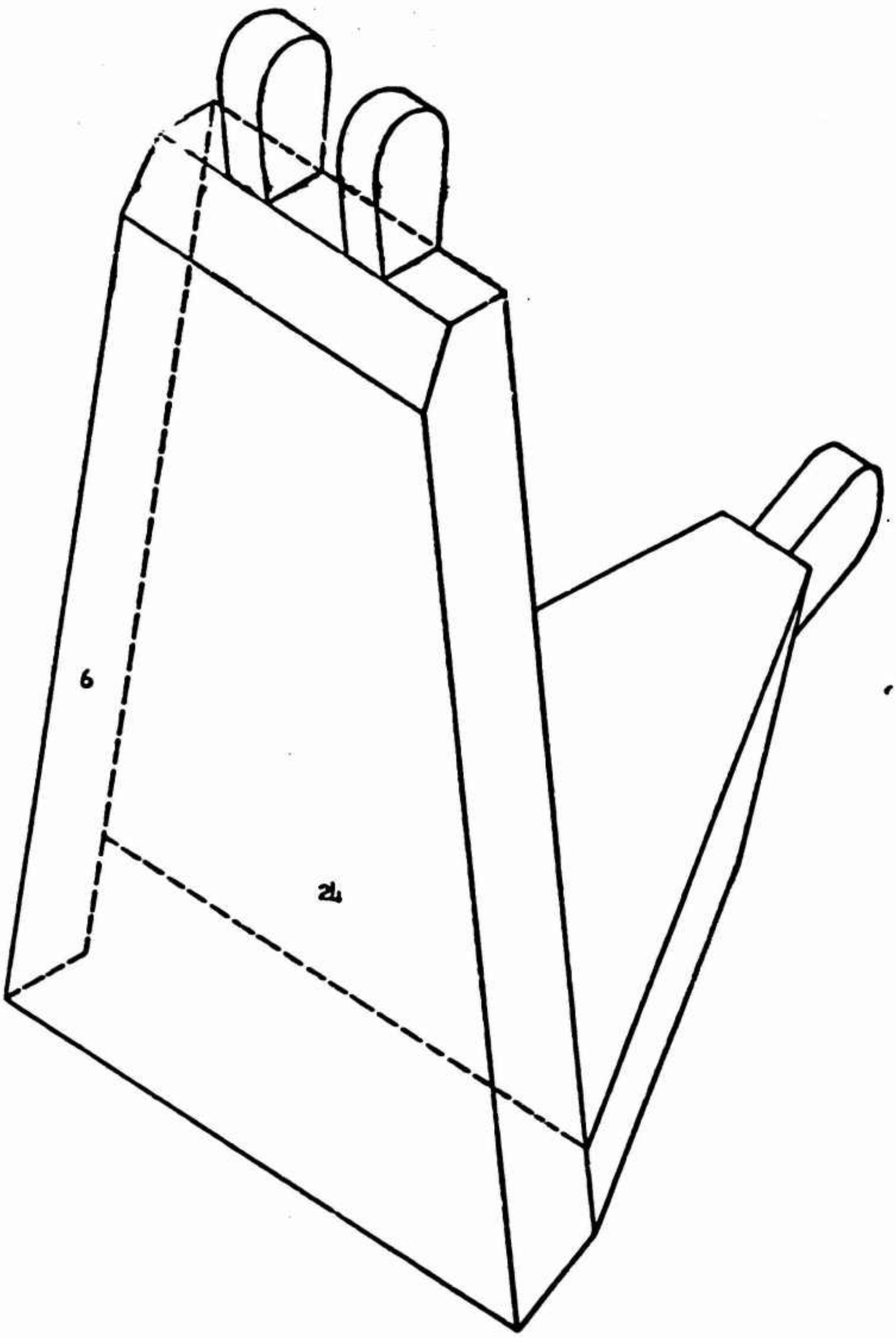
Upper panel, right [illegible], full penetration type weld joint, hexagonal tubing showing location of [illegible] by [illegible] number



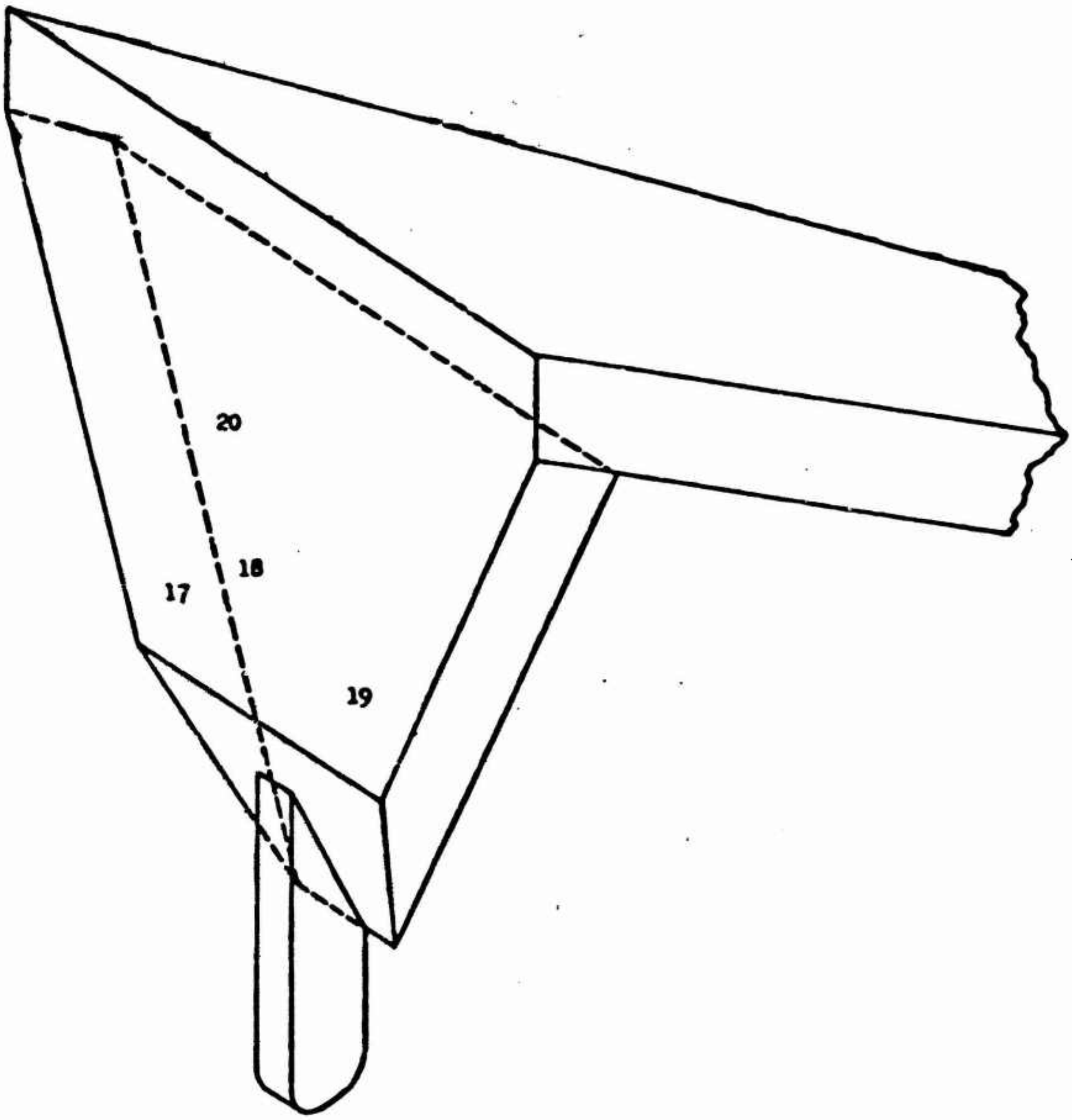
Upper panel, right section, structural type weld joint, square tubing showing location of hits by round number B-6



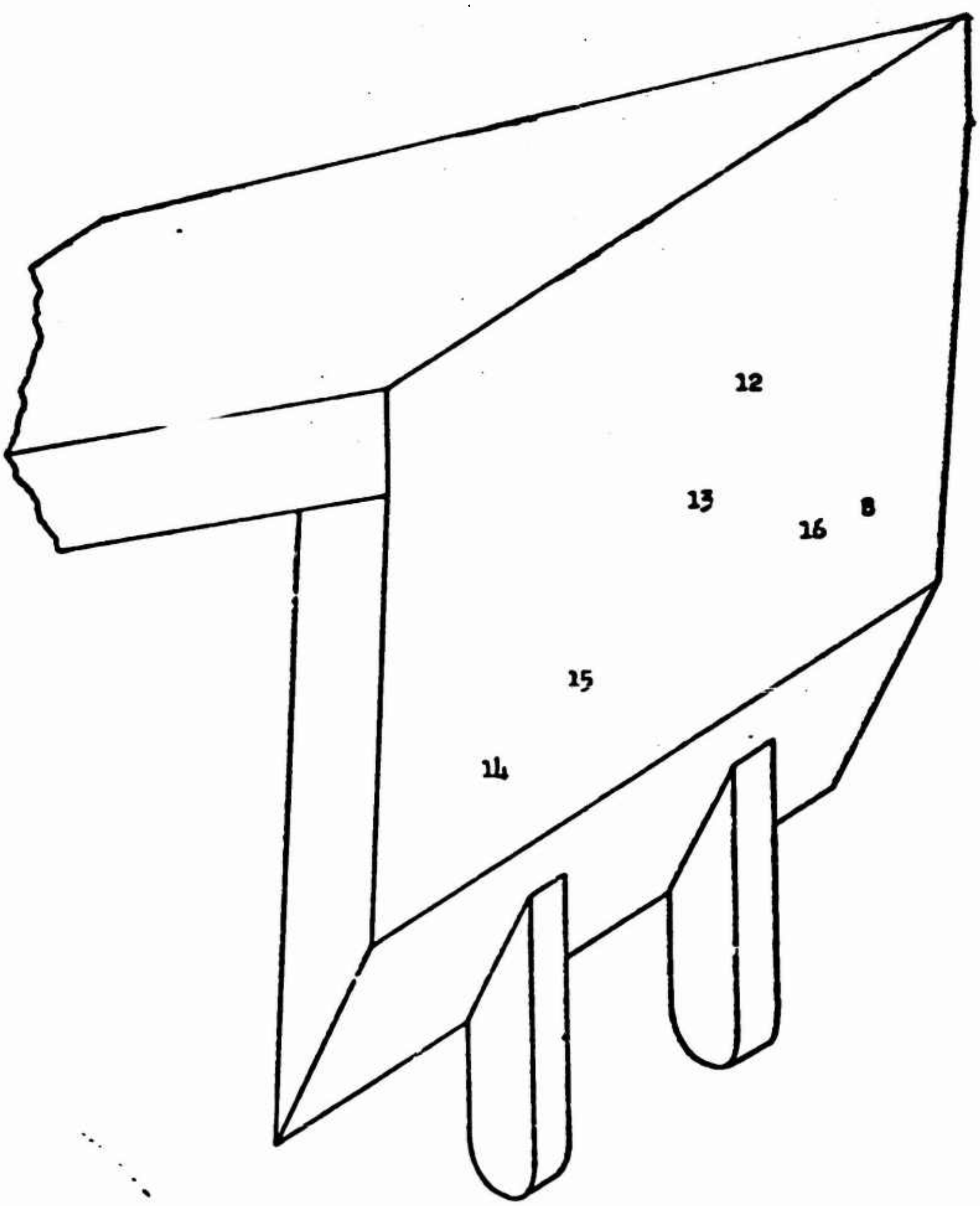
Lower panel, right section, structural type weld joint, square tubing showing location of hits by round number



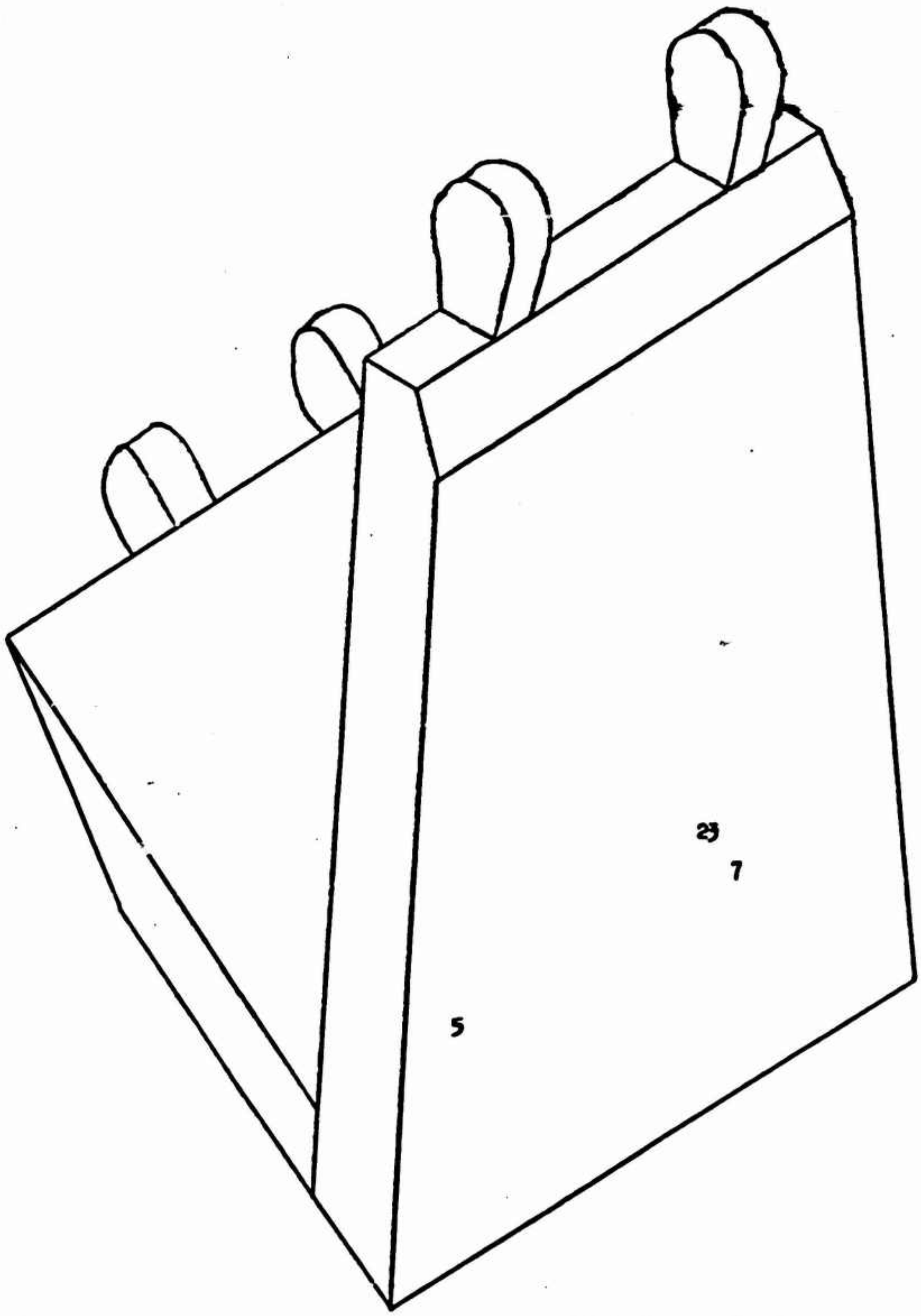
Upper panel, center section, full penetration type weld joint, square tubing showing location of hits by round number



Lower panel, center section, full penetration type weld joint, square tubing showing location of hi's by round number



Lower panel, left section, structural type weld joint, hexagonal tubing showing location of hits by round number



Upper panel, left section, structural type weld joint, hexagonal tubing showing location of hits by round number